

## 19.

## A Consideration of Evolutionary Hypotheses in Reference to the Origin of Life.

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(Text-figure 1).

### INTRODUCTION.

The living organisms of today are thought by most biologists to have evolved from more or less dissimilar ancestors. In fact, since the time of Charles Darwin biologists have addressed themselves, in the main, to establishing evidence to support or demolish various propositions concerning the mode of evolution, as set up by him or others who followed him to a greater or lesser extent. It seems not to have occurred to many such students that the importance to be attached to interpretations of the results of their studies must vary with our ideas concerning the origin of life. Since we are in no position to make any postulates, it may be useful to consider the various ideas that have arisen from time to time in reference to their bearing on the acceptability of any particular evolutionary hypothesis.

We may go along with Lotka (1925) in his policy of resignation concerning a definition of life without in any way encountering difficulty in an attempt to discuss the possibilities of origin. Many of the attempts to explain the origin of life have come from non-scientific groups and most of these may be dismissed with a few words. All are included in this discussion since their many interlocking ideas make it essential at least to mention each one.

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### CONCEPTS OF THE ORIGIN OF LIFE.

Although superficially numerous, see Woodruff (1936), all the ideas that have been put forth concerning the possible origin of life are reducible to two basic patterns. These may be discussed separately

for the purpose of considering their tenable contents in reference to the adequate interpretation of evolutionary experiments and arguments.

1. *Planted life forms.* The idea that life may have been planted on the earth from some exterior source has always been attractive, but today it seems less reasonable than ever before. The idea divides into two parts.

a. *Normal cosmic behavior.* One idea has been that simple, very resistant particles drifting through space from other planets or similar bodies may revive to an active life when happening to land on a body of suitable environment. Arrhenius (1908, 1911) by ingenious reasoning even went so far as to suggest that thermophilic bacteria rained on the earth from possibly Venus, being impelled by the radiant energy of the Sun. This is mentioned in this connection merely to indicate that such possibilities have been given consideration by thoroughly serious persons. Certainly modern experiments on the effects of low pressure and temperatures have shown nothing tending to make this an impossibility as has been indicated, for instance, by Goertz (1928). Venus itself as a source of living substance would seem unlikely on the basis of the view of Wildt (1940) who argues for a negligible amount of water and an atmosphere of formaldehyde. See also Jeans (1942). Such a condition would not seem likely as a life source, in spite of the fact that certain molds and dipterous larvae appear to thrive on relatively low concentrations of formaldehyde in aqueous solution. Since Venus evidently rotates, although its speed has not been determined, it would appear that its nearness to the Sun, surface temperatures as high as 60°C having been recorded, would also stand in the way of the continued existence of protoplasm at any place on its surface. The effects of unfiltered solar or other radi-

ation in space, moreover, may represent a very real hazard. Oparin (1938) on this basis presents a very convincing argument against the possibility of survival under such radiation.

In effect, this idea would have interstellar space occupied by viable motes passing from place to place, along with the matter and radiations already known to be there. Such a condition would provide for a polyphyletic origin of terrestrial life, if evolutionary capabilities be ascribed to such organisms. Lipman (1932) thought he had succeeded in reviving bacteria from the interior of stony meteorites. Oparin (1938) dismisses this study by expression of the belief that contamination was responsible. Actually, while such may have been the case, Oparin gives no foundation for so assuming, other than his well-reasoned argument against organisms surviving the radiations of interstellar space. He wrote, "The organisms which he [Lipman] succeeded in isolating were identical with the bacterial forms existing on the Earth. This makes it very probable that, in spite of all his precautions, Lipman did not succeed in preventing earth bacteria from contaminating the meteorites while they were ground to a powder. Even in different regions of our planet there are different forms of microorganisms, and it would be extremely strange if exactly the same bacterial forms found on the Earth were present also on some remote planets." Exception is taken to this last remark, for if Lipman is right, such results, on the contrary, are exactly what one should expect. Since meteorites are continually falling to earth, one then should also expect a continual seeding of forms capable of surviving such transit. These then would be expected to be common on the Earth in proportion to its ability to support them in active life. This, indeed, also might well lead to a spotty distribution dependent on their needs. Beutner (1938b) also rejects such a possibility but submits no further closely reasoned arguments. Jones (1940) treats the subject in a similar fashion.

**b. Special events.** The planting of organisms on earth, on the other hand, may be thought of as a special event, more or less unique in cosmic history. Anything that could be conjured up to induce such an event would be classified here. The creation of life by decree would come here and would be practically the equivalent of the planting of a culture by some space-traveling, superior animal. Space travel is one of the most recent serious aspirations of man and as yet is seriously handicapped, to say the least, on technological grounds. If extra-terrestrial beings have developed such an art, we certainly have no evidence of it, but the fact that there have been no

visits to earth establishes nothing. It might even be imagined that life on earth is the remnant of some ill-fated expedition from another body from which only food animals survived. The possibilities of this sort are limited only by one's imagination and have been well covered by the writers of scientific fiction, and need not longer detain us here.

Other special events in the nature of a cosmic accident happening but once could make a single planting. Such an accident would provide for a monophyletic origin or a polyphyletic one to the extent of the variety of organisms in this single seeding. One thinks of the cluster of asteroides between Mars and Jupiter that supposedly represents a disrupted planet of considerable size. Its disintegration must have scattered material far and wide.

Fantastic as these notions may sound, there is but one other basic pattern of source that has been suggested which, as will be seen later, also has its fantastic side. The idea that living entities were created by fiat is a widespread one among theologists' mysticisms, which, with minor variations, is the common property of many theologies. Such ideas could belong in the category of special events, if not mere figments of wishful thinking.

**2. Spontaneous generation.** The long-discredited belief in spontaneous generation, experimentally unsupported, is nevertheless the idea which most scientific men seem to think best accounts for the origin of life. By the simple expedient of pushing the event far enough back into geologic time to prevent any kind of experimental approach and postulating an unknown but suitable environment, many seem to have eased their minds. This interpretation of life origin likewise divides into two parts parallel to those of item number one.

**a. Chemical evolution.** Given a sphere such as the Earth, chemists, physicists, astronomers and geologists have shown that a chain of events must follow due to the interaction of forces involved. Radioactive degradation, the salt concentration of the ocean, and so on, come to mind, which it is unnecessary to discuss at length here. See, for example, Clarke (1924), Fairchild (1938) and Jones (1940). The point of this is that chemical evolution proceeds systematically according to the second law of thermodynamics and is very definitely identifiable as a kind of inorganic orthogenesis. Thus we have a world stage in which the inorganic props and scenery are changing by an orthogenetic or "built in" process. Oparin (1938) devotes nearly an entire book to visualizing how such chemical changes took place. He gives by far the most careful analysis and the most plausible picture of a cooling



Earth. Whether all his details are sound and whether events lead automatically to living entities or not, it is hard to deny the basic soundness of his chemical evolution. Beutner (1938) arrives at a very similar conclusion, differing chiefly in the order of chemical events but lacking the close reasoning of Oparin. Riddle (1939) sketches his similar views with extreme brevity. Jones (1940) gives a presentation of the theoretical and observational data of astronomy, indicating what is known and fairly inferential of the conditions on other planets in reference to the basic needs of life.

If the idea is valid that in this process there automatically comes a time and a concatenation of events which grade from the strictly inorganic to the organic and the sentient, then we have life beginning as of necessity as a part of a general "orthogenesis." As such an event would hardly occur simultaneously throughout the world, presumably there would be started various orthogenetic series, the first advanced in development as compared with the later. This should go on until the period of its possibility is passed by the general orthogenesis of the whole system, repetition becoming impossible when the stage is sufficiently changed. This point would be passed presumably when there were no longer any large sterile areas. Oparin believes that early sterility is *absolutely essential* for a life origin of this sort. The pre-living organic components would simply be broken down on earth today, long before they reached anywhere near the living state, by the activities of living beings, according to his views.

Lichtig (1938), on the other hand, disregards this point and supposes the transition from lifeless to living matter to be taking place more or less continuously, indicating a widespread polyphylogenesis.

Herrera (1942) proposes an interesting and startling theory which would derive life from the sublimation of volcanic emanations, after years of close study of the life-resembling behavior and physical appearances of a tremendous number of chemical substances. As he indicates, this, too, would imply a continual synthesis of life, unless some peculiar but necessary factor was present but once in the Earth's history.

**b. Rare accident.** If, on the other hand, we do not consider the origin of life as definitely part of the general increasing entropy, then we may consider it as an "accidental" event repeatable as often as the needful circumstances repeat. This, of course, is pure, spontaneous generation in the simple sense, and no doubt, when referred to known physical law, apparently leads such students as Smith (1932) to refer somewhat poetically to life as "an eddy

in the second law of thermodynamics." See Pike (1939) for a recent discussion of various views on the subject.

Both these views may lead to polyphyletism, the first definitely orthogenetic and the second not necessarily so by virtue of questioning the full and simple operation of the second law in living systems.

If, as thought by various students, the origin of life occurred by unique "accident" another element is intruded. This view arose and gained force by the failure of Pasteur *et al.* to produce life by simple means, and the large evidence that life, as we know it, is produced only by pre-existing parents. The rare accident view is perilously close to the fiat creation of theologians, differing largely in use of words, especially since it is doubtful if any sect ever believed that the creation of human beings was an "accident."

This rare accident view should make for a monophyletic origin of life and leave the way open for any evolutionary process whatever. Judging from the literature of evolution, it would seem that most workers in that field imply that they are interpreting their results on the assumption of an origin of this sort. Either the rare accident or the straight chemical evolution could lead at first, at least, only to an orthogenesis. Paired species, parallel specializations, and parallel mutations certainly suggest at least a "charge" of similar potentialities as a recurrent phase in any group of sufficiently numerous organisms. These views are conditioned by whether one considers life as a highly probable or improbable result of the operation of statistical mechanics.

**3. Interaction of methods.** Of these several views, it will seem that evolution could conceivably proceed by any method in all but one. That one, as a part of general chemical evolution, is definitely linked with orthogenesis. All those items in which life would arise by the ordinary working out of natural processes (1a and 2a) would be expected to lead to a polyphyletic condition. A special planting accident (1b) could be either mono- or polyphyletic, while a rare accident of spontaneous generation (2b) would be monophyletic. This interaction is especially pertinent in the case of chemical evolution (2a) and natural seeding from outer space (1a). Since sterility is perhaps necessary for the first, the second presumably could not successfully be brought into play. If extensive seeding did occur early enough, it could, on this basis, check chemical development of the basic organic compounds.

Before proceeding to a consideration of some current biological ideas in reference to the preceding, it may be best to discuss certain theoretical considerations basic to the establishment of life systems.

## NON-PROTOPLASMIC SYSTEMS.

Active life processes as we know them are remarkably limited in their temperature range. It is evident that it must be below the coagulating point of essential proteins (these may range from about 35° to 70°C), and above the freezing point (scarcely below 0°C). Many various forms are able to survive protracted periods far below this, but are in a state of suspended activity until the temperature is raised again. See, for example, Goertz (1938). Warm-blooded animals may, of course, be active below this temperature of environment, but their life processes are going on at a *higher temperature* by virtue of their very pretty trick of operating an internal heating plant.

Since the chief solvent of body fluids is water which exists in the liquid phase only between 100° and 0°, here are essentially the broad limits, 100° never being reached because protein coagulates at a lower point and 0° being slightly passed on the down side because of the lowered freezing point of the mildly saline body fluids.

These remarks, naturally, refer to surface pressures. Actually many aquatic organisms exist at much greater pressures, as, for example, the abyssal fish of great depths with pressures of tons per square inch. Here temperatures may be such as would cause the fluids to change phase at surface pressures, but this is merely an expression of the pressure-temperature relationship. Extremely light pressures, on the other hand, are limited by the greatly lowered boiling point, resulting in a rapid vaporization and loss of fluids. Actually, in nature, active life is limited in the higher atmosphere by low temperature and apparently by low oxygen content, but considering what low concentrations of available O<sub>2</sub> some aquatic animals thrive on, this in itself might not be insurmountable. However, unlike the combination of high pressure and low temperature, the combinations of low pressure and low temperature, with the resultant change of phase of H<sub>2</sub>O, at a fairly low level of chemical activity may be enough to check active life. Nevertheless, extreme conditions in this direction have been survived for short periods. Insects have been placed under the influence of highly efficient vacuum pumps and rapidly brought to a vacuum comparable to that of interstellar space and lived to survive an immediate return to normal surface conditions, Lutz (1929). Obviously this could only be a transient phenomena because the great moisture loss would quickly result in death.

It is evident, however, that while terrestrial animals well cover the gamut of temperature range in their normal activities, most live much closer to their minimum pressure threshold than to their maximum.

The truth of this is constantly attested by the pressures under which caisson workers survive and the relatively slight altitudes that force aviators to don masks or pressure suits.

Anaerobic organisms are all of a small size and are so presumably of necessity because of the low combustion rate to which their particularly limited metabolism is restricted.

Thus, life, as we know it, is very sharply restricted in a number of directions; by temperature, the effects incident to pressure, and oxygen, either freely supplied or broken out of the substrate. After these comes a host of others going to make up the milieu necessary for the survival of any particular form. All such life is concerned with a single though slightly variable gel-like compound — protoplasm, or as Beutner (1938) expresses it, "life, Carbon's outstanding property." The actual basic autocatalytic activity, as is pointed out by Alexander (1939), is properly only referable to "... the simplest self duplicating units — chromosomes and their constituent genes, mitochondria and possible subcellular symbionts." If there is analogous activity going on or possible in other systems of chemical and physical combination, we are not cognizant of such. Baldwin (1937) writes in italics "... that the conditions under which cell life is possible are very restricted indeed and have not changed substantially since life first began." With the extensive knowledge of life forms now available, it would seem that the terrestrial existence of non-protoplasmic life forms is exceedingly unlikely. Henderson (1913) discusses at length the unique position of carbon in this regard and Jones (1940) makes much of the tetravalence of carbon atoms.

If we consider such matters in a broader way, the question naturally arises as to the possibility of equivalent activity in physical systems covering quite other ranges of temperature. Obviously, what we call life is either a unique phenomenon of a very tiny temperature range, or it is not. Many doubtless would consider it mere foolishness to speculate on other possibilities. However, a consideration of various features of it, at the very least, makes it possible for us to obtain a better understanding of the peculiarities of life activities in the range in which we know it exists.

As a starting point, for a basic requirement, there must be solids, liquids and gases present in some specific temperature range if the inhabitants are going to be sufficiently like known life forms to be called equivalent or analogous. Thus the higher one goes on the temperature scale, the fewer solids and liquids and the more gases there will be found until that point is reached

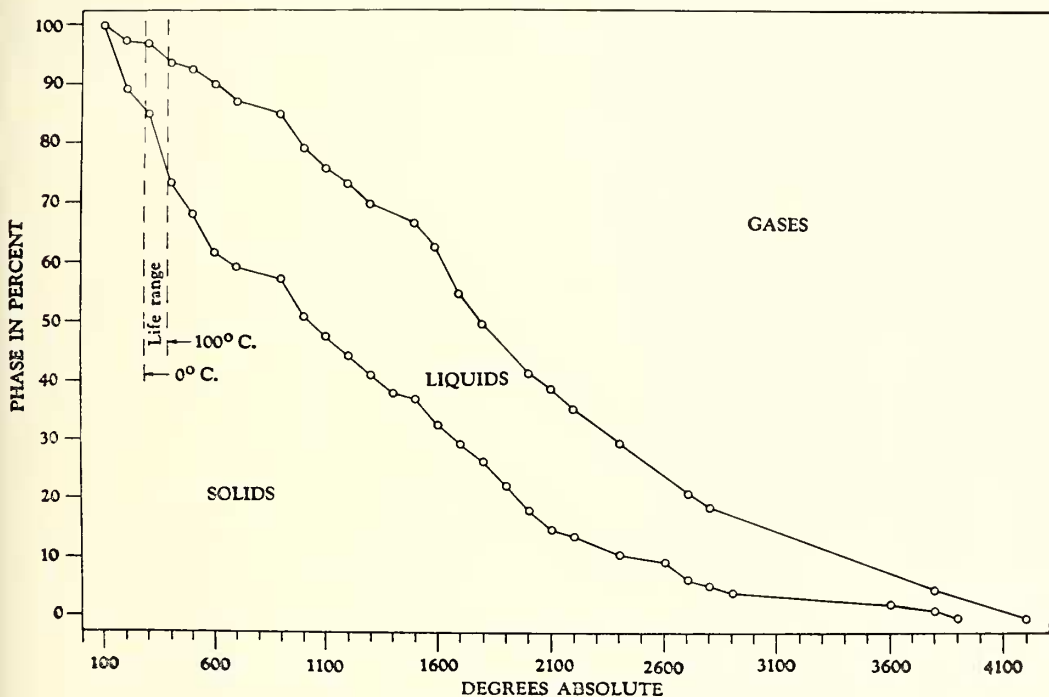


where only a state of highly excited ions exist—a state of complete incandescence. Descending, more and more solids are found and less and less liquids and gases, until absolute zero is reached where no chemical activity is possible.

If the melting and boiling points of the elements are plotted, they form a regularly ascending series from absolute zero. If the phases of the elements are expressed in terms of percentages, a chart, as in Text-figure 1, may be constructed. It will be noted that our life range is very close to absolute zero as compared with the whole scale. These remarks consider only the elements. A study of the possible compounds, which would be of great importance, is a task before which a corps of physicists and chemists might well quail. However, it would appear that the various compounds possible at the different temperature levels, because of the statistical nature of the known and expected possible combinations of elements, would all go to produce curves not dissimilar in form to those obtained for the elements as shown in Text-figure 1.

In connection with a consideration of the

distribution of phases represented in various temperature ranges, the relative abundance of the separate elements enters as an item of considerable importance. Since oxygen, nitrogen and hydrogen occur on Earth in considerable quantities, it is possible for large amounts of water and an atmosphere comprised mostly of oxygen and nitrogen to be present when the suitable temperature range and other features have appeared. It would, on the other hand, be impossible to have an atmosphere in which large quantities of krypton were present. If an organic system were to be based on an environment of some of the less abundant elements it would be seriously restricted. Two conditions can be conceived. One would be such that the important materials were widely spread but highly dilute, placing the need of great effort and consequent strain on any energy exchange system so based and in this manner limiting it sharply. The other would be that the needful materials were concentrated at some focal point and there be relatively abundant. This would restrict such a system on a geographical or spatial basis. Until some hypothetical conditions at an-



Text-fig. 1. Phases of the elements at temperatures from  $0^{\circ}$  to  $4200^{\circ}$ . The temperatures, expressed in terms of absolute degrees, are grouped in classes of  $100^{\circ}$  each and the index figures read as the higher limit. Thus 100 should be read as from  $0^{\circ}$  to  $100^{\circ}$  absolute. The phases are expressed in terms of percent. of the total number of elements. Due to certain chemical features such as sublimation and the fact that complete data are not available for every element, there are some minor difficulties in the construction of such a chart, but these in no way destroy the basic nature of the curves as shown. See text for an explanation of "life range" as here indicated.

other temperature range have been postulated in some detail, to which are to be fitted some equally hypothetical creatures, it is pointless to pursue the item further. The studies of Goldschmidt (1937) on the known distribution of elements in the Earth's crust would seem to be fundamental to any such consideration. See also Russell (1941).

While it is sufficiently obvious from the above that the quantities of individual elements present would have a limiting influence on energy exchange systems of various hypothetical kinds, there could be conceived very definite mechanisms. Although such basic building blocks to known life as nitrogen, carbon, oxygen and hydrogen are sufficiently abundant, it should be remembered that many of the less common elements are needful to the present life on Earth. Iodine, for example, an important element in the living processes of many forms, is not an abundant substance. Furthermore, according to Clarke (1924), the only elements that are represented by more than one percent. of the terrestrial elements are oxygen, silicon, aluminum, iron, magnesium, calcium, sodium and potassium, in the order named. For the first listed he gives 49.2%, descending to the last with 2.4%. All are found in organisms but most are not present in a massive sense. On the other hand, carbon in this list shows only 0.08% and nitrogen, 0.03%. It is thus clear that in the present life system some of the basic materials are comparatively rare. The discussion of Goldschmidt (1937) on the mechanics of concentrating influences on the rarer elements is especially pertinent in this connection. See also Lotka (1925) for further discussion of the relative abundance of elements, their distribution and especially their availability, concentration and circulation.

Thus far we have not mentioned that other important element in the maintenance of living systems—radiant energy. It is hard to conceive of a hypothetical system without a primary or secondary source of some radiant energy as a prime mover. Since astronomers have given us a great amount of spectrographic data on radiant energy, not only in the Milky Way but from far off nebulae, for our purposes, at least, it is safe to speculate on the gamut of wave lengths sprayed out into the universe. Their relative similarity is perhaps their most striking feature. The effects on other systems, for example, the transparency and fluorescence of various substances to differing wave lengths and related matters, is too complex to be entered upon casually and would not be sufficiently significant at this point.

With these items in mind, we can make a few tentative propositions of what life-systems, if they are to be analogous, would require at any temperature-pressure range.

1. The lower the temperature the greater the variety of solids available for body-building, while the higher the fewer and more limited these would be.

2. Inverse to this would be the variety of fluids and gases for the seas, atmospheres, and body fluids, with an increase in kinds and complexities with increased temperatures.

3. The range of the temperature-pressure relationship would have to be such as not to change the phase of the body structures except in a manner analogous to that for protoplasmic life.

4. Radiant energy would have to be such as to maintain a source of prime moving force and the systems would have to be able to utilize it directly or indirectly without self-destruction.

5. Some system of energy exchange by continuous chemical activity would have to be possible in any milieu imagined.

6. With these elements the origin of life forms would be presented with the same basic problems already discussed for life on Earth. Speed of development and evolution (chemical activity) would be slower in each successive lower temperature range. Thus the length of time required for each cooler period would have to be progressively longer for complex entities to develop.

It should be clear that transfers from one temperature level to another, in an evolutionary sense, could hardly be conceivable. In connection with this, it is apparent that protoplasmic life would be nearly the last, or the last, of such a hypothetical series. In other words, our temperature range is close to the lowest at which it is easy to conceive of such activity (see Text-figure 1). This is for two reasons: (1) so many substances are locked up as solids, limiting the possible liquid and gaseous environments, and (2) the level of energy is so close to complete entropy that the activity is necessarily of a low grade in a purely chemical sense.

Stated another way, the foregoing should make it clear that life is either a unique event not far preceding a full heat death, or it is near the end of a succession of similar phenomena that occur in a series of focal points as non-connected modes along a descending temperature scale. It may be emphasized that each range of such activity would have no bearing on the next lower one, any more than the previous chemical combination of a substance bears on any further combinations it may enter as impelled under physical changes.

Since the Earth supposedly existed at a temperature too high for protoplasmic life prior to its present condition, the question naturally arises as to the existence of a



previous similar activity at a slightly higher temperature, and if such may have existed, what are the chances of finding some evidence of it. Since we have no idea as to what range such a thing might have occupied, for sake of illustration we might take the range of  $500^{\circ}$  to  $600^{\circ}$  absolute. This is equal in span of temperature to our life range, but not far above it—perhaps not far enough to be fair to the thesis. It has been selected at random for purposes of illustration but, nevertheless, an examination of the condition of the elements is of interest. Instead of about seventy-eight percent. of the elements being solids, about sixty percent. would be solids. There would be about twenty-seven percent. liquids as against our fifteen percent. and gases would be about thirteen percent. as against our seven percent. For example, the following solids in our life range would be liquids: selenium, lithium and sulphur, while iodine and bromine would always be gases. Various elements between the range of  $500^{\circ}$  and  $600^{\circ}$  would change phase as various points were passed. For example, cadmium, thallium and bismuth would melt and freeze while certain forms of phosphorous would boil and condense. Lead would occur as a liquid in very hot regions, for it melts at  $600.4^{\circ}$ , and in the presence of other substances (fluxes) below that value.

In a world so conceived, what chance of fossil survival would its "organic" remains stand on a drop to present temperatures? What is known of igneous rocks, their crystalline structures, consolidation and metamorphosis would certainly seem to preclude the survival of any structural entity frozen to our relative frigidity. Our earliest fossil-bearing rocks are so clearly of present temperature ranges that we simply cannot look hopefully to such sources for evidence.

The great variety of carbon compounds known to man and the theoretical possibility of stupendous numbers of others leads Beutner (1938b) to consider life a peculiar property reached by the proper combinations of that element. Silicon has been frequently suggested as a conceivable alternate, within our life temperature range, largely because of its comparable ability to build a large number of compounds. This has been most recently discussed by Jones (1940). Silicon, it may be noted, is not so involved in energy exchange systems of which we have knowledge. While not being disposed to debate the unique position of carbon, we may submit that a mere multiplicity of "building blocks" does not necessarily mean that an endless variety of structures will actually be built nor that a comparatively few types of building blocks preclude construction. Actually there are relatively few of the many known carbon compounds to be found in living en-

tities although surely there are many more present not as yet recognized.

Beutner himself seems to be largely concerned with the ingenious devices of Butschli, Traube, Leduc, Herrera, Jennings and Crile, many of which show simulated lifelike activity not involving organic compounds. Although these structures are of extreme interest in various connections, it does not seem that they are likely to throw much light on the question of the origin of life, possibly excepting the work of Herrera. Since living entities are clearly controlled by the same physical conditions that control non-living units, it should not be surprising that various arrangements can be made of non-living substances that react in ways similar to some of those observed in living entities. The elaborateness of some of these reactions is distinctly interesting and should be of aid in explaining behavior, morphological detail and pattern, but certainly not origins. The striking nature of these contrivances would seem to be limited only by the ingenuity of the experimenter and were it not for their spectacular nature would not be thought of in connection with a discussion of the origin of life any more than would be experiments which show that animal heat is comparable to inorganic combustion or that HCl in the stomach acts in a manner identical to HCl in a test tube. The models here under consideration can be seen to move or grow and are comparable to studies in locomotion or growth in a manner similar to the above suggested chemical comparisons and probably useful to an equivalent degree. It should also be clear that primarily the right chemical compounds must be obtained for "livingness" to begin. The form or movements come later, and obviously these physical aspects may be extremely various whereas the chemical nature of life, as we know it, is limited to one type of chemical system of energy exchange.

Rosett (1917), in describing his particular "design" of an artificial osmotic cell, gives an excellent evaluation of the over-emphasis and under-emphasis that has been accorded such studies by various schools of thought.

Beutner (1938a) recognizes the separate nature of morphology and "the power of self-reproduction" and writes, "Obviously, then, living organisms, according to our present conception, have two distinct general characteristics:

"1—The power of chemically transforming the material of their environment (or food material) into their own substance;

"2—The ability to develop diverse forms."

The first item is a definition for an autocatalytic enzyme and the second is clearly not a basic item in the nature of life but is

a historical statement based on what has apparently happened and which condition may be needful for long continued survival.

He considers viruses as having no morphology when he writes, "A filterable virus possesses the first general property to its fullest extent, but nothing of the second one." It might be equally well argued that its morphology is on a submicroscopic basis as indeed it would have to be, and that it possesses morphology in the sense that any molecule does, especially since the entire atomic theory is based on structure and arrangement (morphology).

#### EVIDENCES OF MODERN SCIENCE.

If we examine the evidences of modern science and not the more or less generally accepted speculations based thereon, we have to dig rather deep to obtain anything of real significance.

For the theologists' mysticism there is none at all, except wishful thinking and sentimentalism. This is not to be taken as a mere derogatory dismissal, for until the idea of extra-sensory perception can be fully disposed of, simple dismissal cannot have the full assurance formerly possible. However, if such a concept is to be even considered, it would automatically reduce to the consideration (1b) (page 132).

For the idea of life as planted, there is present-day evidence of the great resistance of spores and other living objects to extreme low temperatures and of their presence in the substratosphere. Coupled with this is the known force of radiant solar energy as a possible propulsive force. However, there is also the known destructive force of unfiltered radiant energy in interplanetary space, Lewis (1934). Planting as a cosmic accident would thus seem to have nothing whatever any longer to support it. Carbon found in meteorites has been thought perhaps to represent the remains of extra-terrestrial life forms. The nature of impact of these objects is such as to make such a source exceedingly unlikely. Elemental life forms have been claimed to be recovered from the interior of stone meteorites by Lipman (1932), but the true source of their origin is still undetermined. See Oparin (1938).

For the concept of spontaneous generations, several ideas have been brought forward. Born in the biological ignorance of early man, to explain his failure to understand the appearance of small animals, a mode long disproved, it nevertheless lingers in a modified form as a possibility. The part of chemical and physical changes in a system of mixed substances gives a point of departure on the assumption that the world is a cooling sphere. Under the influence of solar radiation with the Earth acting like a gigantic Soxlett extractor, it is easy to

imagine life as a spontaneous event on the reaching of a certain state. Today, with the virus situation as it is, the differentiation between living and non-living seems to be largely academic, Stanley (1937, 1938a and b), Rivers (1939), Hunt (1939) and Martin and Fisher (1942). It is to be emphasized, however, that viruses or even unicellular units may not in the least be primitive, but may just as well, so far as present evidence goes, be derived from the products of living metazoan bodies, Breder (1936). Even if Oparin's broader views are accepted, viruses would not necessarily have to be considered as primitive. However, this may be, whether viruses came first or last, or all the way along the line, there is no really objective line of demarcation.

It is not necessary for us in the present discussion to go into a close consideration of the steady state which life represents or the electric fields which surround such units of electro-chemical activity. The work of Northrop & Burr (1937) may be noted, in passing, as indicative of this field of approach to the basic nature of livingness.

No matter what restrictions or modifications must be made, the terrestrial water circulation acts basically like a Soxlett extractor and strongly influences the present chemical composition of the ocean, Lotka (1925). That the blood plasma of animals is not very divergent from it in a chemical sense, and protoplasm itself is clearly related, makes only a small leap of imagination necessary to assume a relationship. It has been argued most recently by Macallum (1926) and Beutner (1938b) that the first land animals may have simply carried some of their earlier aquatic environment along with them. This would seem to be too pat a statement, for it would seem that if oceans and organisms are all part of one evolving chemical system, it would be quite natural for both to partake of considerable chemical similarity. Redfield (1934) gives some very suggestive data in this connection. This resemblance of organisms would naturally be to a fluid in which there was considerable matter in solution rather than to the solid substrate or to fresh water. The osmotically low value of fresh water, if nothing else, would hardly be friendly to the consolidation of a primitive gel. See Pantin (1931) and Baldwin (1937). Croneis & Krumbein (1936) discuss the hypothesis of Chamberlin to the effect that life may have originated in soil, largely on the basis of the dispersive effects of oceanic conditions. Under water, subsoil conditions would seem to obviate the principal objection. Perhaps the primordial gel was interstitial in the sands of early beaches, an arena of life now occupied by many specialized forms, and which only recently has begun to receive the attention of biologists that it undoubtedly deserves.



The above remarks apply equally well to either a normal chemical evolution or a rare "accident."

#### EFFECTS ON SCIENTIFIC THOUGHT.

The main purpose of the present paper is to discuss the effect of these various hypotheses on scientific thought. The different ideas that have been advanced to explain the methods of evolution are usually given and discussed as though the origin of life had no bearing on the subject. This is certainly not the case but in evaluating the plausibility of any of them we must necessarily consider their merits against a background of what origin of life is presupposed. Even in cases where there are alternates, the one selected causes certain strictures or produces certain effects implied in all reasoning derived therefrom.

The primary forms of organic transformation that have been suggested by biologists may be reduced to four basic concepts:

(1) Inheritance of acquired characteristics (Lamarckianism), now discarded because of the failure of experimental evidence.

(2) Natural selection in the Darwinian and neo-Darwinian sense and more or less under critical appraisal.

(3) Orthogenesis, perhaps, not susceptible of scientific investigation by direct methods.

(4) Mutation in the DeVriesian sense or in the modern version of Goldschmidt (1940) involving violent and sudden transformations.

All other views seem to be variants or combinations of the above four, more frequently differing in terminology than in content. See Dobzhansky (1940).

Before discussing these varying views in detail, the number of points of origin of life, which also has a marked bearing on the whole question of organic relationship, may best be examined.

Considering monophyleticism versus polyphyleticism, it should be clear that if the latter is implied by the nature of the origin assumed, it is pointless to attempt to build phylogenetic trees that try to tie all forms together. Since most present-day biologists, tacitly at least, imply a monophyletic origin, it must mean that some of the previously discussed ideas of life genesis have been discarded by them. It is evident that while a monophyletic origin may be considered for all concepts, since life on earth must have commenced at least once, such is not necessarily true of every concept. Stated another way, polyphyleticism is possible only if life origin is part of a normal process (planted or spontaneous). While this could also be monophyletic, the assumption of a

rare "improbable" chemical "accident" or planting would almost certainly preclude polyphyleticism.

With the "normal" processes of chemical evolution, an orthogenetic basis of evolution would certainly be expected—simply as a mere continuing of a spontaneous activity. With the planted processes, either repeated or rare, or with a rare chemical accident, it might or might not be expected. In other words, any of the conceivable sources of life could carry with it the possibility of some orthogenetic scheme "built into" organisms. Under such a scheme there would be nothing to prevent the possible occurrence of mutations in the Goldschmidt sense. In fact, it might well be that such should be expected and thought of roughly as somewhat analogous to the change of phase in inorganic "orthogenetic" systems occurring when certain points of development have been reached. This concept is, of course, not unlike that of the emergent evolution of C. L. Morgan (1923).

Natural selection in the coarsest sense would no doubt operate from the first. Whether it carries over into the refinements generally expected of it is another matter, but one on which the present discussion may be suggestive. If organisms have some such orthogenetic "program" built into their beings, it is certainly not surprising that neo-Darwinians have much trouble in trying to explain natural selection on a micrometric basis.

Adaptation, in the teleological sense, these thoughts do not tend to support, since the organic units must by random or other means find themselves in environments in which they could continue as such. Here again only the coarse effects can be argued for with any strength. All others could be just as well accounted for by some straight process of orthogenesis in which the primary organisms either found themselves in an environment sufficiently suitable or perished if they did not.

It is of more than passing interest in this connection that Spencer & Melroy (1942), on a basis of their results on exposing bacteria, protozoa and flat worms to carcinogenic agents through many generations, wrote, "The biological generalization that certain environments may be ontogenetically harmless but phylogenetically lethal is suggested."

This should not be interpreted to mean that organisms are not affected by their environment except to survive or perish. However one may care to try to account for the interesting associations of highly specialized organisms of today with their environment, these refinements certainly appeared at a relatively late date in phylogeny unless one wishes to assume that this feature of evolution is an inherent property of organisms.

If it is, it is rather amazing how many animals have lost the faculty of transmitting environmental effects (acquired characters) at least quickly, and how well they manage without it. This thought is, of course, related to the complete inability of any one to establish satisfactorily the inheritance of acquired characters.

The well-known habit of flounders of quickly matching their background in considerable detail may be considered a matter of individual behavior. This operates, and presumably without conscious effort, through sense organs (the eyes) but is in truth no more remarkable than the fact that we stand on two legs without conscious effort. Very possibly a flounder on a wrong background is as uncomfortable as we are when out of plumb. Since any creature *necessarily* is limited to the equipment it is endowed with, it normally makes use of such as it has and survives or not, according to the results obtained. This, of course, is a far cry from the implications of the adaptationists who for long have certainly over-played the niceness of fit between organism and environment and have failed conspicuously to explain the development of complex organs, such as eyes, for example. That it is at least possible for flounders to reach sexual maturity without benefit of the usual color matching changes has been shown by Breder (1938). His fish may have survived on a purely random chance or it may have consistently kept its conspicuous coloration out of sight by more adequate burial than is usual to the species.

All this obviously implies that what an animal does with its equipment is considerably superior to what particular kind it has, in a functional sense. The divergence of the forms of organisms can certainly be used to support this view as well as the essential basic similarity of what they all do. What it does is more closely associated with the restrictions of environment than what it has. Stated another way, a Mammoth can be frozen in the Arctic tundra for generations and essentially retain its form outside of temperature ranges at which it can do anything. Or again, an insect might have its form changed (and be ruined) by being caught in the beak of a bird. It could be saved from this by flying away (if it had wings), crawling between grass blades (if it had none), or even just by sitting very still. This is merely fitting its activity to its morphological limits to suit its environment. That these morphological limits may be exceedingly various is evident from the above—but what it does must fit its needs much more closely; thus a long-legged and a short-legged insect may find shelter beneath the same leaf. It is little wonder that the “fitness” and lack of “fitness” of animals to

environment as based on morphology have given rise to endless discussion.

Returning to the basic argument, however, it should be clear from the preceding, without laboring the point, that before such activity can take place at all the primitive organic entity must first fit its environment in a purely physiological sense. The temperature thresholds that hem in our kind of life are clearly first in physiological importance and these must be substantially maintained long before adjustments between one animal and another can even be conceived. The losses of species due to glaciation and other major changes so far overshadow micro-adjustments that one is forced to wonder at their alleged importance. If an orthogenesis could be established, all the observed results could be reasonably explained, whereas the reverse cannot be said for the usual concepts of pure natural selection and other similar ideas.

Finally, the thoughts here expressed lean strongly to the conception of life origin on Earth as a physico-chemical evolution of the sort conceived of by Oparin (1938). This inevitably carries with it a strong bias to orthogenesis, places emphasis on the fundamental limiting factors of life, on the importance of what an organism does with its equipment rather than what equipment it has, and questions the micrometric functioning of selective processes. Furthermore, in an evolving physico-chemical system in which one reaction follows another, no one would think of referring to the disappearance of some compound, as the result of this activity, as natural selection. Only when such become sufficiently complicated and individuated does this word put in its appearance (biological literature) and in this sense would seem to be reducible to the status of a convenient phrase to hide behind. Lotka's (1925) chapter on “the statistical meaning of irreversibility” is very suggestive in this connection as is the physico-chemical determinism of Alexander (1939).

The function of reproduction in connection with this problem is far from clear. Oparin (1938), in spite of his interesting discussion of coazervate systems, becomes somewhat vague at this point. Since it is one of the generally obvious basic differences between the animate and inanimate, it is in serious need of further critical study from new approaches. Perhaps here, after all, lies the key to the secret of life and what may be responsible for the effects that have given biologists so much trouble of interpretation. Since viruses apparently do not have need for the elaborate mechanisms of reproduction to be found in the larger life forms, it may well be that the entire business of both sexual and asexual reproduction is a means of circumventing the re-



stricting influences of elaborate morphological structure, a need that does not arise so long as the naked enzymes have no more than molecular structure with which to deal.

If we consider life as a retardation of a general increasing entropy it follows that by the peculiar nature of living processes we have in effect a building up of a certain amount of back pressure to the degradation of energy. This, so far as we know, always occurs in individuated clumps of heterogeneous matter—the individual of the biologist. This goes on for a time and finally the individual disintegrates. From the first, all such individuated organizations are fighting a losing battle against the general downward trend of available energy, which is evidently bound to culminate in death. This places reproduction in the role of casting off new colonies of such aggregates of material—like a long relay race up a down-moving escalator. Whether this necessarily culminates in the eventual loss of the race and the generally accepted heat-death is still not clear, at least for our little niche in the space-time frame. *A priori*, there seems to be no particular reason for things working just that way, for surely it is conceivable that some sort of energy exchange system could be imagined that would not necessarily exhaust itself in a short time, passing on only a tiny fragment saved from the forces of destruction, if it were not running a breathless race up a down-escalator.

These ideas lead naturally to a piece of pure speculation that it is tempting to indulge in and which really is at the heart of the perhaps seemingly unconnected items that comprise this paper. If we visualize all known items within our universe as a simple expression of physico-chemical activity, as a part of an increasing entropy, it is clear from the preceding that we are very near the end, in a cosmic sense. Life, as we know it, appears well along to the end and gives the appearance of a manifestation that seems to give back pressure to the common lowering of energy levels. Up to the appearance of autocatalysis all activity would run along well enough according to the straight-forward operation of the Second Law. Finally the autocatalysts emerge into ex-

tremely complex individualized units possessing tremendous urges to run counter to the forces of their surroundings, which urges are more and more forceful as that strange element "consciousness" appears. Finally we reach the stage of present man with his deliberate, elaborate and more or less successful attempts to modify his environment. With this has come careful, though blundering, thought processes attempting to understand what it is all about, purely emotional at first but grading finally into an intellectual and objective plane. One wonders if this drive is a new one directed against the continuing entropic drift similar to but superimposed and of a later order than the fundamental sex drive that seems to be the final difference between the inert drift downward of the non-living and the hold-back of living entities. Looked at this way, there is little wonder that such operations are a source of trouble and a general preoccupation.

This, of course, is as far as we can see, as it is the level of activity at which we now cut off. What then of the future? Two possibilities seem to appear. First that the life activity merely peters out sooner or later, and it is in truth just one hold-back on a descending energy scale (and there may have been others, as already suggested) and will pass on with the universe to complete entropy. Secondly, it may be that life activity is of more importance than reason dares permit us to postulate. The present activity of man one may speculate upon as part of the physico-chemical evolution now going on but inducing a progressive retardation in the otherwise increasing entropy. This could conceivably result in one of two fashions. One would be an increasing slowing of the process as entropy approaches the absolute. In other words, the evolution of such a physico-chemical system could be expressed by a curve reaching an asymptote. The other would be a complete reversal of trends, perhaps brought about by the "intelligence" of some groups of individuated bits of matter in which case the curve might be something in the form of a parabola, a hyperbola or, fantastically, even a closed figure.

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